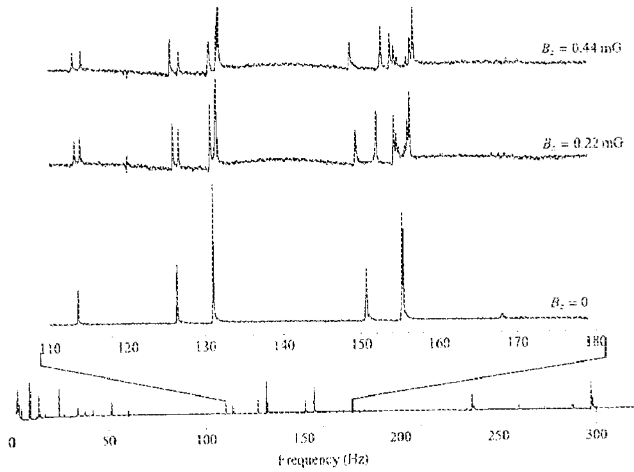

FIG. 4: Effects of small magnetic fields on fully labeled acetonitrile $^{13}CH_3^{13}C^{15}N$. The bottom trace shows the entire zero-field spectrum. The upper traces show an expanded view of the central part of the zero-field spectrum, as well as the spectra in the indicated finite fields.

with a $^{13}CH_3$ group, and confine our attention to the $1 \leftrightarrow 0$ transition with total proton spin $= 1/2$, yielding transitions in the neighborhood of $^1J_{CH}$. Addition of the second ^{13}C splits these levels: $f = 1$ splits to 3/2, 1/2 manifolds, and $f = 0$ manifolds splits to 1/2. Addition of the ^{15}N splits these so we now have $f_a = 2$ or 1, $f_b = 1$ or 0, and $f_c = 1$ or 0. For now, we ignore transitions between $f_a \leftrightarrow f_b$ because they occur at low frequency. Employing the $\Delta f = 1$ rule we expect three $1 \leftrightarrow 0$ transitions, producing doublets: $f_a = 1 \leftrightarrow f_c = 0$, $f_b = 1 \leftrightarrow f_c = 0$, and $f_b = 0 \leftrightarrow f_c = 1$. Transitions between $f_a = 2 \leftrightarrow f_c = 1$ yields a multiplet with six lines, and transitions with $\Delta f = 0$ between $f_a = 1 \leftrightarrow f_c = 1$ and between $f_b = 1 \leftrightarrow f_c = 1$ yield multiplets with four lines. More details are presented in the Supplementary Information.

In systems with small couplings, such as 1-acetic acid ($CH_3\,^{13}COOH$) which has a two-bond coupling, $^2J_{CH} = 6.8$ Hz, it is possible to explore the regime in which the Zeeman interaction is comparable to the J-coupling. Figure 5 shows experimental spectra for 1-acetic acid for the indicated magnetic fields. The large peak that does not split is due to the uncoupled OH group, while the rest of the spectrum corresponds to the $CH_3\,^{13}C$ part of the molecule. Initially, the spectrum appears similar to the 2-acetonitrile spectrum, with a doublet at J, and an additional doublet at $2J$ composed of several unresolved lines. As the magnetic field is increased, additional lines in the multiplet at $2J$ become resolved. At the highest magnetic fields, the spectrum displays the highest complexity, and is no longer recognizable from the perturbative treatment presented above. The smooth trace at the